Tracks: #4 C2 Decisionmaking & Cognitive Analysis

Modeling Support of Effects-Based Operations in War Games

Lee W. Wagenhals* and Alexander H. Levis
George Mason University
C3I Center, MSN 4B5
Fairfax, VA 22030
703 993 1712
703 993 1706 Fax
{lwagenha, alevis}@gmu.edu

* Corresponding author

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **JUN 2002**	2. REPORT TYPE	3. DATES COVERED **00-00-2002 to 00-00-2002**

4. TITLE AND SUBTITLE **Modeling Support of Effects-Based Operations in War Games**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **George Mason University,C3I Center, MSN 4B5,Fairfax,VA,22030**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**		**16**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Modeling Support of Effects-Based Operations in War Games[1]

Lee W. Wagenhals* and Alexander H. Levis
George Mason University
C3I Center, MSN 4B5
Fairfax, VA 22030
703 993 1712
703 993 1706 Fax
{lwagenha, alevis}@gmu.edu

Abstract

The Effects Based Operations (EBO) concept is based on relating actions in a battle plan to overall effects. A prototype system called CAESAR II/EB has been developed to assist in analyzing Courses of Action (COAs) for Effects-Based Operations and evaluating them in terms of the probability of achieving the desired effects. The tool supports both static and dynamic evaluation of COAs by integrating influence nets with discrete event systems modeling techniques. Preliminary operational concepts for using this tool in command and control environments were tested during the Naval War College Global 2000 and the Global 2001 war games providing insights into the appropriateness of these techniques in support of EBO. In Global 2001 the authors worked with different cells and components to produce four models of the complete battle plan to support the planning phase and six quick reaction models to support the execution phase of the game. The interaction of the modeling team with the multiple command and control cells in the game and the potential as a COA decision support was tested and examined. This paper describes the experiences with building and using the models and discusses requirements for enhancements to the modeling techniques generated from this experience.

1. Introduction

Effects Based Operations (EBO), the notion of selecting actions that comprise a COA based on their collective contribution to desired and undesired effects, is not a new concept. It, and other concepts like network centric warfare, try to convey in different ways that technology, in general, and information technology, in particular, can enable us to consider in a serious and effective way the integrated application of all instruments of national or coalition power towards achieving national or coalition objectives. While these concepts have allowed us to go well beyond the construct of massive attrition-based warfare, they have tightened many of the traditional constraints: collateral damage must be minimized, our own casualties must be virtually nil, the long term impact on the well being of native populations should be limited (e.g., do not destroy beyond repair the infrastructure).

Military organizations including the Joint Forces Command and the Naval War College, have been exploring these concepts to determine how they can support command and control in advanced networked environments using virtual collaboration within and between multiple domains to formulate, execute, and assess operations. One ingredient in these explorations has

[1] This work was supported by the Office of Naval Research under grant No. N00014-00-1-0267.

been an increased emphasis on modeling tools and techniques to support effects based planning and execution.

Recent war games and exercises have experimented with EBO as an essential organizing principle for command and control of military operations across multiple echelons. EBO thinking has been enhanced because commanders and decision makers have at their disposal new technology that allows precision attack with weapons of pinpoint accuracy, intelligence systems that provide accurate location of targets, and stealth technology that greatly reduces the requirement of defensive support systems to protect striking weapons, has enabled selective components of adversary systems to be struck with precision to achieve desired effects with minimum risk and destruction. In addition, the complexity of coalition operations and the understanding that an important aspect of warfare is the actions that will take place after the combat operations have ceased, has led to the notion that we should consider alternatives to the concept of maximum destruction attrition warfare.

This has lead to two concepts. The first is that by wording directives to subordinate component in terms of effects, the components will be able to collaboratively plan for the use of resources and actions that will best achieve the directed effects. In collaborative sessions, different components will offer actions that contribute to the effects in the directives and the best set of actions will be selected based on the combined contribution to achieving the effects. The second concept is the need to integrate lower level effects into higher level, overall effects. By focusing on the overall effects needed to achieve objectives and considering a spectrum of lethal and non-lethal actions, COAs can be formulated that use precision intelligence and strike capabilities to inflict the minimum collateral damage while achieving objectives. To do this one must understand and develop a set of effects that, if achieved, will result in the overall objectives and then determine the best set of actions to take, *along with their timing*, to achieve those effects. In modern coalition operations, such actions include not only traditional military attrition based operations, but a spectrum of actions across the instruments of national power employed by coalition partners to influence and persuade an adversary to change his behavior and at the same time maintaining cohesion within the coalition.

There are a variety of modeling techniques that are used to relate actions to effects. With respect to effects on physical systems, engineering or physics based models have been developed that can predict the impact of various actions on systems and assess their vulnerabilities. When it comes to the belief and reasoning domain, engineering models are less appropriate. The purpose of affecting the physical systems is to convince the leadership of an adversary to change its behavior, that is, to make decisions that it would not otherwise make. Thus, the effects on the physical systems influence the beliefs and the decision making of the adversary. Because of the subjective nature of belief and reasoning, probabilistic modeling techniques such as Bayesian Nets and their influence net cousin have been applied to these types of problems. Models created using these techniques can relate actions to effects through probabilistic cause and effect relationships. Such probabilistic modeling techniques can be used to analyze how the actions affect the beliefs and thus the decisions of the adversary.

Thus the EBO concept results in a shift in focus. Instead of focusing on the servicing of a well defined a priori target list, we focus on the effects that we wish to achieve. The target list still

exists and includes both hard and soft targets: from weapons systems, to C2 nodes, to leadership nodes, to infrastructure nodes, to the contents of communications. But the target list is only an intermediate construct, a means to an end, which can change rapidly as the effects we wish on the adversary are being achieved or not. Indeed, the list of possible actions we can take is now much larger as it includes all instruments of national (or coalition) power: political, military, or humanitarian; physical or ideological. The availability of all instruments gives us much flexibility in trying to achieve the desired effects and to avoid undesirable ones. But it also makes the Course of Action (COA) problem and the subsequent planning problem much harder. There are now many alternatives, many choices. The choice of a set of actions, their sequencing, and their time phasing become a problem in their own right.

Considering these EBO concepts, a modeling tool called CAEASR II/EB has been built and tested to focus on the belief and reason aspects of the spectrum of operations. The tool incorporates influence nets as the probabilistic modeling technique and a discrete event system modeling technique, Colored Petri Nets, to support the temporal aspects of COA evaluation. This tool was designed to develop and assess courses of action (COAs) at the operational and strategic level.

During the initial development of the CAESAR II/EB, realistic models were created to test the EBO concepts. However, the use of the tool suite within a working command and control structure had only been postulated. In 2000 and 2001, the Naval War College invited the Office of Naval Research to use CAESAR II/EB tool suite in their capstone, Title 10 War game, Global, to gain insight into its potential utility for supporting COA development and evaluation. These experiences provided an important opportunity to tests these concepts and tools in a realistic environment. At one level, this participation helped illustrate how this approach to Coarse of Action development and selection for effects based operations can be used to support war games. Even more importantly, the participation in the war game provided insight into how these concepts could be incorporated in real-world operational environments. Participation in the game provided information about the sources of the information needed to create the models, the type of expertise needed to build and analyze the models, and the types of collaboration and dialog that needs to occur between modelers, intelligence centers, operational planners, the commander, and command staff. The ultimate question was to determine if these techniques could improve decision making by providing increased insight into the potential consequences of actions.

The rest of the paper is organized as follows. Section 2 describes the CAESAR II/EB tool and provides some insight into the model building and analysis process used with the tool. Section 3 reports on the use of CAESAR II/EB in the Global war games. Section 4 contains observations from the Global experience and provides summarizes the lessons learned and describes future directions for the research.

2. CAESAR II/EB

We have shown that EBO is the notion of selecting actions that comprise a COA based on their collective contribution to desired and undesired effects. To support EBO, at least two problems must be address. The first is to relate effects to actionable events. In this problem, we need to define the set of desired and undesirable effects on the adversary, and then, working backwards,

from effects to causes, arrive at the actions that we have at our disposal for achieving these effects. In the second problem, called the COA problem, we must select from the set of all possible actions those subsets that will yield, with high probability, the effects we wish to achieve and will yield, with low probability, the undesirable effects. Then, taking into consideration constraints associated with specific actions or combinations of actions, the selected actions must be sequenced and time phased. The result is a set of alternative COAs. These COAs are then evaluated against requirements to determine the COA that provides that best likelihood of causing the desired effects to occur and the undesired effects to not happen.

CAEASR II/EB has been built and tested to focus on the belief and reason aspects of an adversary so that potential actions can be related to effects. The tool incorporates influence nets as the probabilistic modeling technique and colored Petri (CP) nets[2] to support the temporal aspects of COA evaluation. These two techniques enable the modeler to create the structure of actions, effects, beliefs, and decisions, and the influencing relationships between them. The influence net provides a static equilibrium probabilistic model that indicates the probability of effects given sets of actions. After an influence net is converted to a CP net, temporal analysis can be conducted that provides, for a given a timed sequence of actions, the probability of effects over time, in the form of a probability profile[3]. Probability profiles can indicate how long it will take for a specific COA to achieve the desired effects, reveal time windows risk when unacceptable probability effects could occur, and provide time windows for indicators of success or failure. Changing the timing of selected actions can significantly change the probability profiles.

A two stage operational concept that uses the two modeling techniques to perform COA analysis has evolved through tests in realistic scenarios[4]. In the first stage, intelligence analysts and subject matter experts develop an influence net and use it to determine the set of actions that will comprise a COA. Once the influence net has been created, it is converted to the CP net so that operational planners can perform temporal evaluation in stage two. The goal of stage two is to determine and recommend the timing of the set actions that give the best set of acceptable probability profiles for all effects.

Influence nets have been used since 1994[5] to depict the causal relationships between actions and events. They are a variant of Bayesian Nets. Influence nets are acyclic digraphs. The nodes represent statements or beliefs with which a probability value can be associated. The directed arcs represent a directed binary relationship between two nodes. Two parameters characterize the

---

[2] Jensen K. (1997). *Coloured Petri Nets: Basic Concepts, Analysis Methods and Practical Use. Volumes 1, 2, and 3. Basic Concepts*. Monographs in Theoretical Computer Science, Springer-Verlag, Berlin, Germany.

[3] Wagenhals, L. W., Shin, I., and Levis, A. H. (1998). "Creating Executable Models of Influence Nets with Coloured Petri Nets," *Int. J. STTT,* Springer-Verlag, Vol. 1998, No. 2, pp. 168-181.

[4] Levis, A. H. (2000). " Course of Action Development for Information Operations," *Phalanx,* Military Operations Research Society, Vol. 33, No. 4.

[5] Rosen, J. A., and Smith, W.L. (1996). "Influence Net Modeling with Causal Strengths: an Evolutionary Approach," *Proc. Command and Control Research Symposium,* Naval Postgraduate School, Monterey, CA. pp. 699-708.

relationship, called influences, and are denoted by h and g. The first parameter, h, represents the strength of the influence that a parent node has on a child node, if the parent node were to be true. The second one reflects the strength of the influence if the parent node were not true. Both h and g can take values in the closed interval [-1.0, 1.0] which means that the binary relations can be either promoting (+) or inhibiting (-). In addition, each node with parents has a parameter called the baseline probability, which is an estimate of the likelihood of the proposition represented by the node without regard to any influences. After an analyst creates an influence net and assigns the value of the g, h, and baseline probability parameters throughout the net, the values are translated into conditional probabilities for each node with parents using the CAST (for Causal Strength) algorithm[6] . The influence net can then be used to propagate probabilities from the nodes with no parents (action nodes) to the nodes with no children (effect nodes). The underlying assumptions in the algorithm result in a substantial simplification in the knowledge elicitation process when SMEs are asked to provide values for the influences.

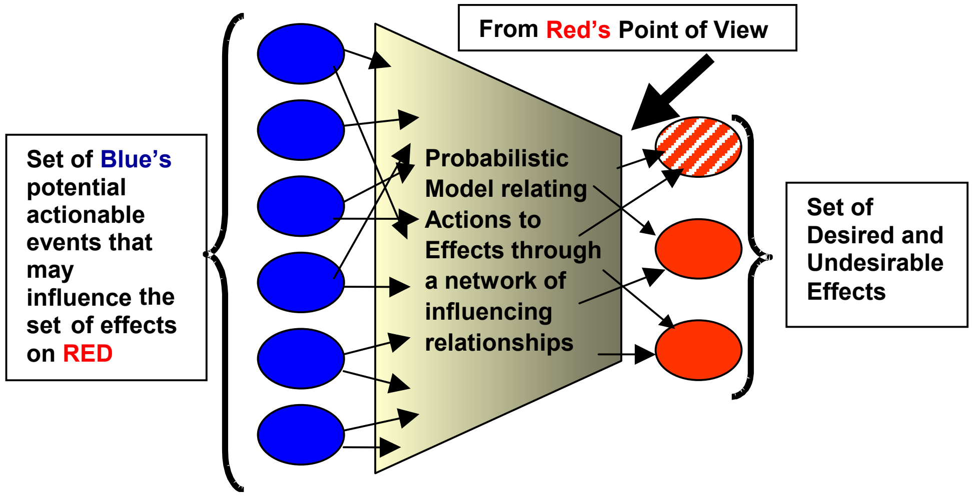


Figure 1. Modeling Actions and Effects

Figure 1 shows a high level view of the concept of an influence net. In developing the Influence net, the modelers incorporate two types of knowledge about an adversary referred to as Red. The first involves the actions, events, beliefs, and decisions and the relationships between them. This knowledge is captured in the structure of the influence. First, objectives and commander's intent are translated into overall desired and undesired effects, sometimes stated as decisions that may be made by the adversary. For example, we may be trying to convince an adversary not to decide to launch an attack or not to use particular weapons or systems. The influence net starts with these desired and undesirable effects. Analysts then select the key factors or beliefs that the adversary could consider in making the key decisions that result in the desired and undesired effects. Then each key factor is examined to see the factors that would influence it. In this manner (working from right to left in Figure 1), analysts use knowledge of the relationships between the reason, belief and decision making processes of the adversary, and build the influence net until they arrive at the adversary beliefs on which the planner, Blue, can have an impact through its actions. Analysts then create nodes that represent all the potential actions that are available to Blue at the extreme left and proceed forward from those (from left to right) until the influence net is completed. After the structure of the net is created, the analyst adds the second type of knowledge, the h and g values to all of the influencing relationships, and the baseline probability to each node that has at least one parent.

[6] Chang, K.C., Lehner, P. E., Levis, A. H., Zaidi, A. K., and X. Zhao (1994) On Causal Influence Logic, Technical Report, George Mason University, Center of Excellence for C3I.

Once the influence net is completed, the analyst and us it to determine the best chance of achieving the effects for a given set of actions.

Several tools are available to represent an Influence net. They have comparable graphical user interfaces (GUIs) like the one shown in Figure 2 for the Campaign Assessment Tool (CAT)[7] tool developed by both AFRL and George Mason University. A color scheme is used to denote ranges of probability values with red denoting very low probability and blue very high. In Figure 2, the left parent's probability of occurring is near 1, while the right one's has probability near zero. Given the influences (h's and g's) that have been converted to conditional probabilities via the CAST algorithm, the Influence net algorithm computes the probability that the statement encoded in the child node would be true with probability about 50%. Changing the probabilities of the parents changes the probability of the child.

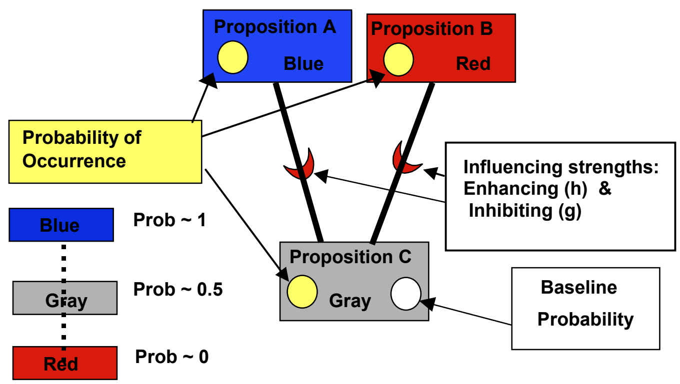


Figure 2 Influence Net Graphical Interface

Once the Influence net has been completed, it can be used to evaluate the impact of actions on the effects (decisions) of interest. This can be accomplished by executing the influence net or by sensitivity analysis. To execute the influence net, the analyst sets the probabilities of a set of actionable events to either zero or one, depending on whether the action is planned or not, and evaluates the influence net. Algorithmically, this means that the tool propagates these probabilities until all effects are accounted for at the nodes with no parents. These nodes represent main effects. The results of this evaluation are visually shown by the color of each node (shades of red, gray, and shades of blue) and by providing marginal probability values of each node in a small circle on the lower left corner of the node. An analyst can experiment with the influence net by changing the probabilities of one or more of the actionable events and seeing what the effect is on the key decision nodes. Ultimately, the analysts can determine the subset of the potential actions to recommend to decision makers and back up the recommendation with rationale derived from the cause and effect relationships and strengths.

Once the analysis of the influence net has been completed and the actionable events for the COA have been selected, planners assess the availability of resources to carry out the tasks that will result in the occurrence of the actionable events. The resultant plan will indicate *when* each actionable event will occur. Clearly, it is not only the selection of the set of actions that will lead to achieving the overall desired effects while not causing the undesired one that is important. The timing of those actions is critical to achieving the desired outcomes. Evaluation of the impact of the timing is carried out using the CP net implementation of the influence net. Since the Influence net does not contain temporal information, the analyst must provide it as an input to the CP net. In general, there are several types of temporal information associated with the CP

[7] The Campaign Assessment Tool is a government owned software package under development by the Air Force Research Laboratory, Information Directorate (AFRL/IF).

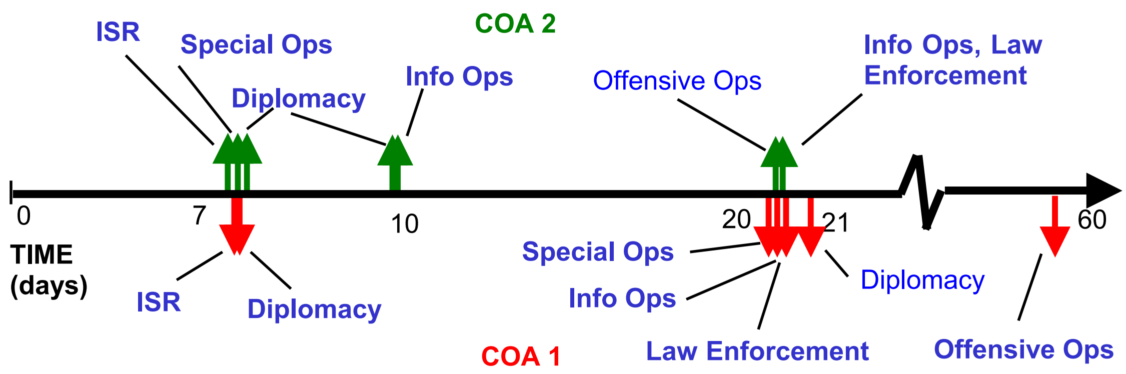


Figure 3 Two Courses of Action (same actions, different time-phased sequences)

net representation of the Influence net; one associated with the input scenario and others with the model itself. We will deal with the input scenario and time delay information in this paper.

The input scenario can be described in terms of the actions chosen in the selection of the Course of Action (COA) and the time at which these actions occur. The actions are modeled as events, which means that they occur instantaneously. An example of two COA scenarios is shown in Figure 3. The actions and their timing of COA1 are indicated above the time line while the same set of actions with different timing that comprise COA2 is shown below the time line.

Because influence nets assume the independence of causal influences, it is possible to associate time with either nodes or the arcs of the influence net. These times represent the amount of time it takes for knowledge about a change in the status of any variable to be propagated by some real world phenomenon to the node that is affected by that change. The update in the marginal probability of a node occurs immediately after the time delay. It is these time delays along with the timing of the actions that causes the generation of probability profiles.

Figure 4 shows the COA analysis environment provided by CAESAR II/EB, the combination of models, and results produced by this modeling construct. It is partitioned into two gray boxes that correspond to the two stages of analysis, static and dynamic. An Influence net model for a given situation, built using the Campaign Assessment Tool, is shown in the upper left gray box of Figure 4. In this particular example, an adversary, Red, has invaded a neighboring country. The Blue coalition is developing COAs that will compel Red to decide to terminate hostilities (effect 1) and negotiate with Blue (effect 2). Red possesses dangerous weapons of mass destruction (WMD) that Blue does not want Red to use (effect 3). The Influence net has been arranged with potential Blue actions on the left and the key Red decisions on the right. This is to indicate visually that the effects of the actions are expected to propagate to intermediate effects over time until their impact reaches the key decisions. The visual construct is that there is a time scale associated with the propagation of effects between nodes of the Influence net that moves from left to right. There are six actionable events on the left side of the Influence net. These are candidate actions that can comprise a COA that can impact the three Red decisions of interest. The model suggests that the best COA will be composed of all six actions.

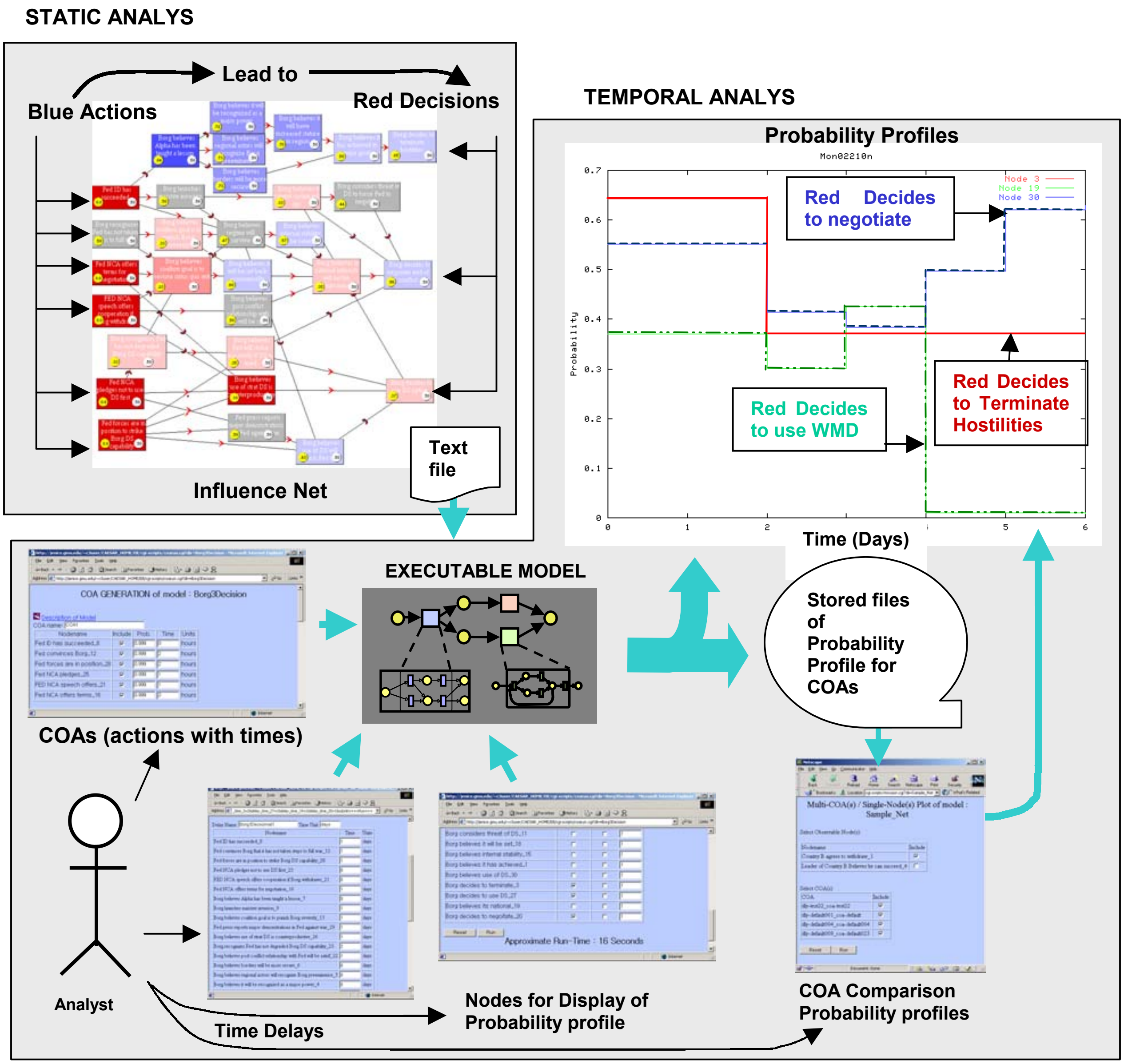


Figure 4. CAEAR II/EB COA Analysis Environment

Once the analysis of the influence net has been completed and the actionable events for the COA have been selected, the influence net is converted to an executable model (CP net) so that a temporal analysis of the COA can be performed. To enable the conversion, the influence net tool (CAT) generates a text file that contains all of the parameters that specify the influence net. This text file is transferred to a web server environment (shown in the lower boxed in area of Figure 4) where it is used by a script to build the CP net. Using a web browser, an analyst is able to run the CP net under a variety of initial conditions by filling out a set of HTML forms that are generated by the server.

To begin such analysis, the analyst specifies the time delay information for the influence net by filling out a HTML form. Once the time delays have been specified, the analyst fills out two

forms in his browser that enables him to specify a COA and the nodes to be displayed. When these two forms are filled out, the server sets the initial conditions in the CP net, runs it to generate the probability profiles that show the marginal probability for those nodes in the net as a function of time, and displays them in the browser. Server also automatically stores the values needed to plot the probability profiles in a file for later use in comparing COAs. These profiles can indicate how long it will take for the effects of the actionable events to affect various nodes in the Influence net and time windows when probabilities may have unacceptable values. By changing the timing of the actions in the COA, the analyst may be able to eliminate these unacceptable windows. The analyst will most likely concentrate on the probability profiles of the key decision nodes, the nodes with no children. An example of three probability profiles for a single COA is shown in Figure 4. The annotations have been added to for clarity. Notice that for this COA, the likelihood that Red will decide to use WMD decreases and then increase before it finally reaches a very low value. This indicates that there is some risk associated with this COA. The analyst will attempt to discover an alternative timing scheme that will reduce this risk caused by the rise in the likelihood of WMD use. To compare COAs the analyst can fill out a HTML form in the browser to generate plots that show the probability profiles of nodes for different COAs. The ultimate output of the analysis is a recommendation, along with the supporting rationale, for a particular COA.

3. CAESAR II/EB in Global

In 2000 and 2001, the Naval War College invited the Office of Naval Research to use CAESAR II/EB tool suite in their capstone, Title 10 War game, Global, to gain insight into its potential utility for supporting COA development and evaluation. These experiences provided an important opportunity to tests these concepts and tools in a realistic environment. This section describes how the tool was used and the lessons learned from the experience.

The conduct of these Global war games involved a two-stage process. The first stage, the planning stage, took place over several months before the actual play of the game. During this stage teams composed of game players and the staff of the Naval War College developed assessments of the situation as determined by the game scenario, establish Commander's Guidance and Intent, and evaluate and recommend COAs that will be executed during game play. The first stage was followed by the actual play of the game where the selected COA was executed. This two-stage process emulates the planning and execution processes that occur during real operations. Participation within both stages by the CAESAR II/EB team allowed the examination of the use of the modeling and analysis concepts to support the EBO modeling, COA selection, and the execution assessment processes discussed in the introduction.

The organization for Global was based on cells that emulated the strategic, operational, and the tactical levels of military command and control. The cells included the national level command, CINCs (Strategic Level), a Joint Task Force Commander with full staff, and cells for several component command centers (operational level). The decisions and directives generated by the components were provided to a game floor where umpires used various models and simulations to determine the outcomes at the tactical level. The war game used both an adversary (Red) team and a Blue team that were in two-way communication with the game floor. As the game floor received tasks and directives from the Blue players and the Red players, the game floor

determined the outcomes of those tasks and returned information to the Blue and Red players that was commensurate with the intelligence, surveillance, and reconnaissance (ISR) assets each had deployed.

One of the key observations from the Global experience is that it is critical to place the EBO analysis capability in the command and control organization were it will have access to both a team of subject matter experts who understand the adversary and the operational planners. For the execution phase of the Global war games, a special cell called Blue's Red Assessment Team (BRAT) was created. This team was located in a "reach-back" cell that was separate from the standard intelligence cells. The BRAT had the function of providing quick reaction analysis during game play of the adversary's potential actions and reactions to the Blue COA. This cell reported directly to the JTF command center. Because the cell was populated with numerous subject matter experts (SMEs) from intelligence, information operations, WMD effects, and nodal analysis, it was decided that this was the most appropriate location for CAESAR II/EB capability during the game play (execution). During the planning phase of the game (the first stage), the BRAT was not operational. Thus the CAESAR II/EB team operated as a self-contained analysis entity and provided the results of its work in a freelance manner to the planners who developed the basic COAs.

The Naval War College refined the EBO concept for Global 2001 by creating a structured approach to developing the battle plan. Using commander's intent, the CINC, CJTF, and Component Staffs would determine specific effects to be achieved through a coordinated set of Blue actions. Each effect would be expressed as an Effect Directive. Each Effect Directive would be decomposed into a set of Effect Missions to be carried out by coordinated efforts of the Components of the JTF. Each Effect Mission was further decomposed into specific Effect Tasks that would be carried out by specific forces controlled by the Components.

The CAESAR II/EB team built influence nets to support the analysis of each of Effects Directive. A mapping was established between the elements of each Effects Directive and the nodes of each influence net that supported the analysis of the Effects Directive. Tasks mapped to actions, Directives mapped to Effects, and intermediate nodes represented Missions in the influence net. Addition intermediate nodes were created to account for Red reasoning and beliefs that were not explicitly contained in the Directives, Missions, or Tasks, but where important consideration Red would make. The full set of Effect Directives included six effects, each with multiple missions and each mission with multiple tasks.

Initially six Effects Directives were established to achieve the six effects:

Effect 1: Red decides against further aggression

Effect 2: Red's neighboring states and the coalition forces are secure from attack

Effect 3: Coalition forces and commercial interests enjoy safe, uninterrupted access to the waters of the region in accordance with international laws and norms

Effect 4: Red forces depart Brown

Effect 5: Red forces depart the disputed territory of X

Effect 6: Red is not capable of dominating the region by force

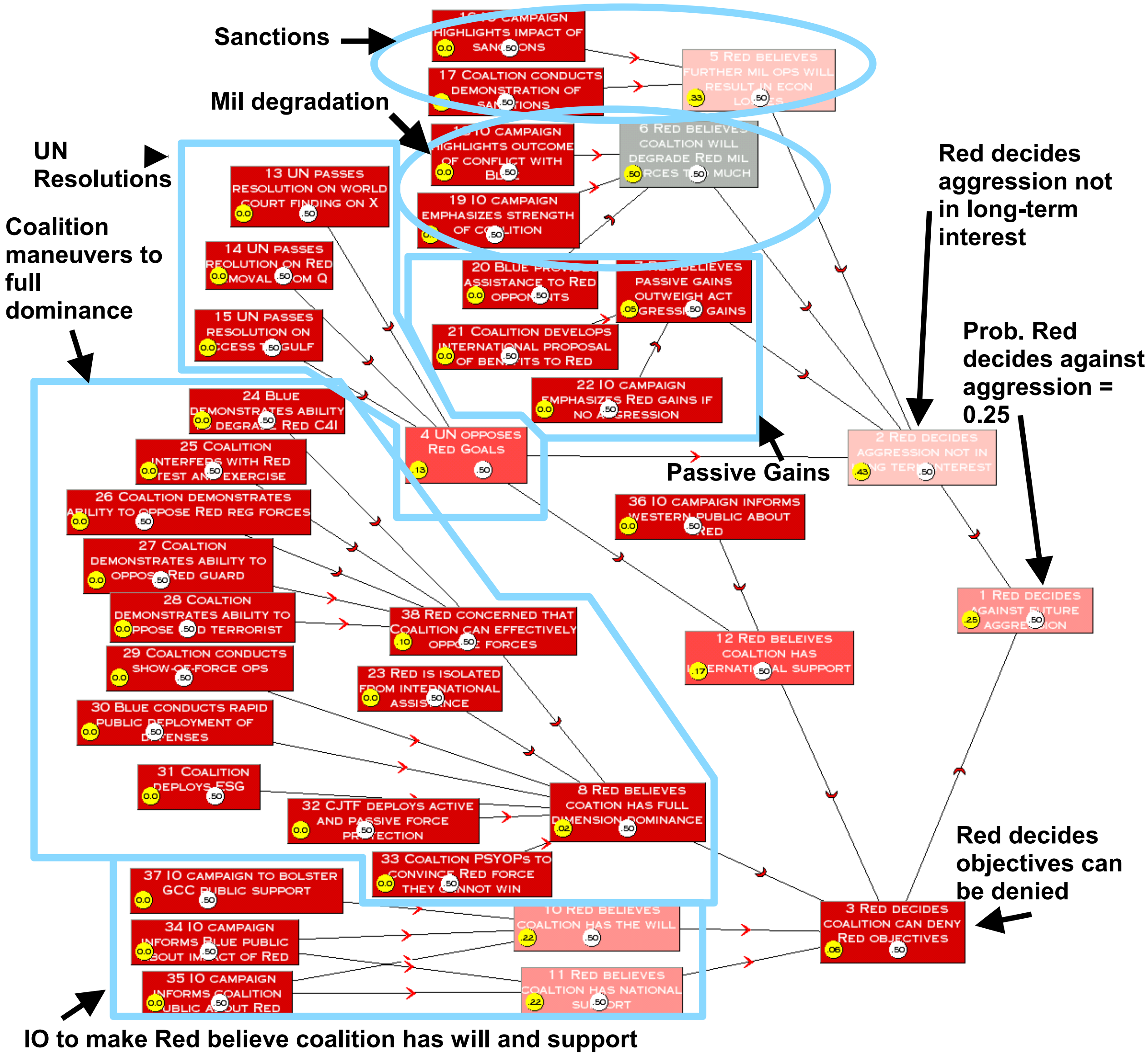
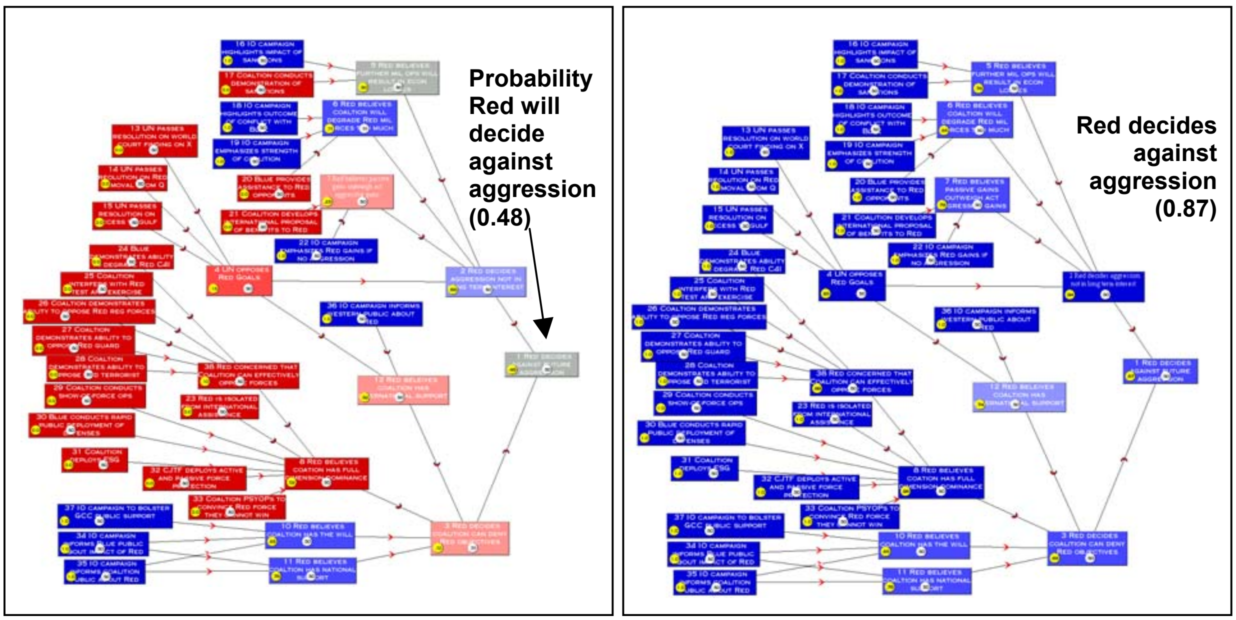


Figure 5. Influence Net for Effects Directive 1

Figure 5 shows the influence net that was created for Effect 1. The right side of the model shows major three decisions by Red, based on Red beliefs. The beliefs are influenced by a combination of Coalition actions. The influence net has been overlaid with boxes and textual descriptions to show different domains of action. These include a combination of diplomatic actions and Information Operations that threaten sanctions against Red while attempting to convince Red that it can achieve its objectives by passive means. The actions also include United Nations resolutions, Information Operations to convince Red that the coalition has the will plus local and

homeland support for military operations if necessary, and the flow and maneuver of forces into the region to create full dominance.

Static analysis was carried out using the influence net to assess the likelihood of achieving the desired effects as different combinations of actions are taken. Usually, non-kinetic actions were analyzed first to see if they have sufficient influence to cause the desired effect without resorting to the use of force. Figure 6 shows two screen shots of the influence net. The first shows that the IO actions, by themselves, increase the likelihood that Red will decide against aggression from 25% to 48%. Certainly, this means that Red may be influenced by the IO campaign, but Red will still be inclined to act aggressively. If all actions are taken, the model says that Red will be much less likely to act aggressively.



Blue Takes IO Actions | **Blue Takes All Actions**

Figure 6. Influence Net Analysis of Effect 1

Temporal analysis was performed to assess the impact of timing of actions on the effects of concern. Figure 7 shows the temporal analysis for Effect 1 for an IO COA with actions taking place at days 3, 8, and 12. The analysis shows how the cascading and cumulative effects of IO actions will begin to accumulate by day 12, but will not reach full effect until day 25.

As the battle plan was built, similar analysis was carried out for all 6 Effect Directives. The analysis gave the planners a better understanding of how the actions in the plan would contribute to the overall effects they are designed to achieve and how long it will take for those actions to reach the maximum probability of achieving the goal. These results were presented to the senior leadership of the game players and the head of the BRAT prior to the game.

During the war game, the CAESAR II/EB team resided in the BRAT cell. Figure 8 illustrates the BRAT procedures for the use of the CAESAR II/EB tool. At the start of each game day, the

BRAT leader would brief the cell on the urgent problems and issues facing the CJTF and his staff. The CAESAR II/EB team converted these problems into questions and effects with the help of the SMEs in the cell. The information provided by the SMEs was used to either modify an existing influence net model or to create a new model that would indicate the impact that Blue actions could have on the effects of interest. Once the model was created, the CEASAR II/EB team conducted sensitivity analyses and then converted the results into a presentation that was given to the BRAT Cell leader. If the BRAT leader approved the presentation, it was posted to the web site and the knowledge wall for access by the various staff members of the JTF and the components who were making planning decisions.

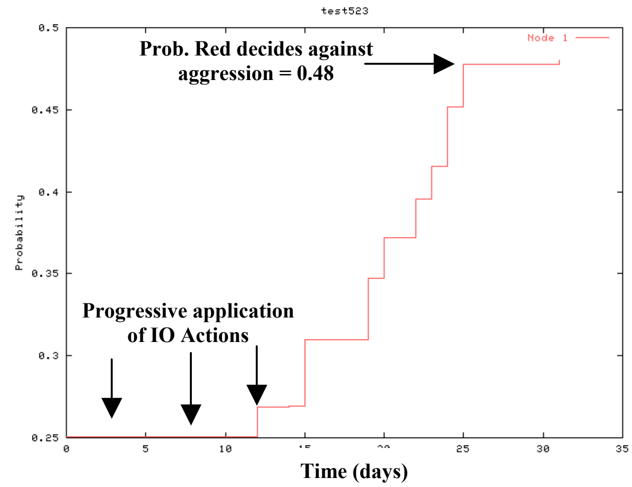


Figure 7. Temporal Analysis for IO COA

It was the goal of the BRAT cell to provide assessments of the situation to the JTF Commander and his staff in time for them to make COA decisions that could be implemented to achieve the desired effects and inhibit or prevent the undesired ones. The BRAT leader expressed this goal as “Being in front of Operations.”

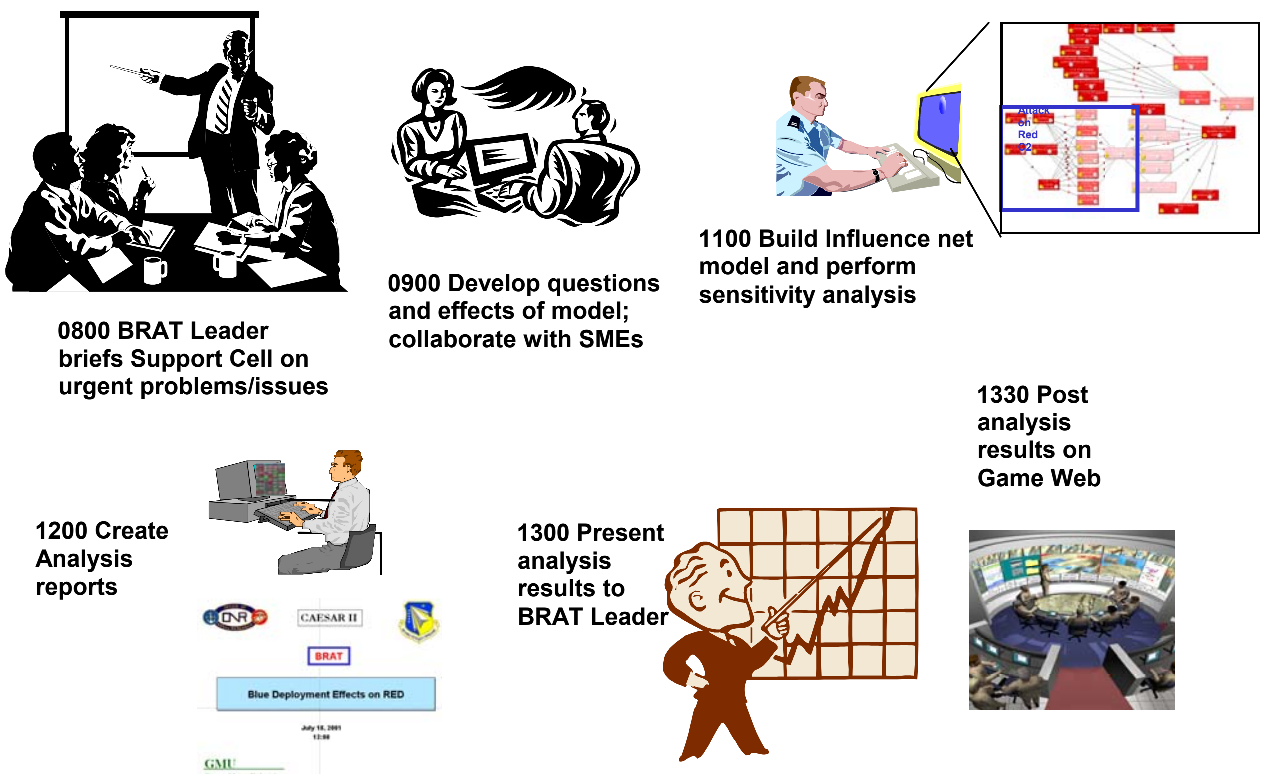


Figure 8. Operational Concept for CAESAR II/EB in the BRAT at Global 2001

The tempo in the BRAT cell was brisk. As the situation unfolded, specific questions arose that could not be addressed with the CAESAR II/EB products that had been created during the planning process. To "stay ahead of operations," new models had to be created and analyzed quickly. In some cases it was possible to modify the planning models to address the immediate questions. This tended to be faster than creating totally new models. In other cases new models had to be built from scratch using the knowledge developed from the modeling effort during planning plus new information generated during the game play. The need to be able to rapidly build influence net models, process them, and develop the presentation of the results provided insights into ways to improve the CAESAR II/EB tool suite.

In general, the CAESAR II/EB was able to respond to the issues and questions in a timely manner. However it is not clear that the results of the analysis were always used by decision maker that could best benefit from the results. This is because there was a very large quantity of information being generated by many sources as the game unfolded. Getting the relevant information to the right decision maker at the right time is one of the main challenges of command and control. Because the concepts of analysis of effects based operation are still being developed and learned, the assessments provided by a tool like CAESAR II/EB are not yet sought by most operators. Instead, the direct recommendations by the BRAT Cell leader was effective in providing the insight to the decision makers.

4. Observations and conclusion

Our experience in Global 2000 verified the value of the EBO modeling concept of CAESAR II/EB and gave the team experience building models to support a war game. As the CAESAR II/EB team interacted with the game players during the game play, it became clear that the tool could not be very effective unless it is used from the very beginning of the war game design. Indeed, based on the experience in the Global 2000 game, the CAEASR II/EB team recommended that the tool be used in the Global 2001 game and that this modeling and simulation approach be used in the *planning phases* of the war game (January to June) both to shape the scenario and to familiarize players with the capabilities so that they can ask for and be given support during the game.

Our experience with Global 2001 verified the value of CAESAR II/EB team participation from the beginning of the war gaming process. We discovered that supporting both planning and game execution requires two distinct types of modeling efforts. The first is in support of deliberate planning prior to the game, and the second involves a quick reaction modeling during the game play. Each type of effort has different characteristics as indicated in Table 1.

Table 1. Characteristics of Modeling Efforts

	Deliberate Planning	Quick Reaction
Preparation Time	Days to Weeks	Hours
Model Size	Medium to Large	Small to medium
Multiple Models	Yes	No

In the deliberate planning phase, multiple models were built. Each emphasized a different aspect of the battle plan and focused on specific effects. These models tended to be large, and it took three to five days to build and analyze each. During the planning phase, the CAESAR II/EB tool helped focus the conceptualization of COAs on the desired and undesired effects of a campaign and how to achieve them. It provided a way of seeing the impact of an integrated set of actions across the spectrum of military and non-military actions. The temporal analysis revealed the amount of time that it may take to reach objectives and revealed time windows when the probability of desired effects decreases or probability of undesired effects increases to unacceptable levels due to improper timing of actions.

During the execution phase of the war game, there was a premium on timeliness. Due to limited resources, the CAESAR II/EB team was unable to monitor the execution of the game and update the planning models with execution information to assess the progress that was being made toward achieving the desired effects. Instead, the BRAT cell concentrated on providing answers to specific questions about the adversary's reaction to actions that were being planned by the operators. To quickly respond to those questions required rapid morphing of existing preplanned models or the development of new models that were tailored to answer the specific questions. The speed with which the CAESAR II/EB team could build a model, do the analysis, and provide the response depended on many factors. Model building requires a knowledgeable and compatible team of SMEs who are familiar with the influence net modeling techniques. The tool must be easy to use, have an interface for rapidly adding influencing strength values and timing information, and be capable of quick model modification to include the ability to cut and paste portions of existing models into new models. The use of pre-formatted templates could minimize the time to generate, interpret, and incorporate the results into the report that presents the results and recommendations. These insights into requirements for EBO tools are being used to enhance both CAESAR II/EB and similar tools are in advanced development by the Air Force Research Laboratories. Along with these tool improvements, the authors believes that there are opportunities to refine the model building process to improve the speed of modeling building and analysis.

The participation in the Naval War College Title X war games provided a laboratory environment in which experiments could be conducted to investigate how CAESAR II/EB and tools like it can be used to support EBO in a real operational environment. From this type of experience operational concepts for the use of tools to support the analysis of effects based operations is evolving. The experience gained in Global will enable EBO teams with tools like CAESAR II/EB to support the development of future war game effects based battle plans and to use them effectively to support COA assessment during war game execution. Insights gained about the tools, the modeling techniques, the processes needed to support EBO including the information needs, organizational issues, and the physical support systems that will ensure that future campaigns are planned and conducted with the focus clearly on the effects to be achieved.

Acknowledgement

The contribution of the GMU System Architectures Laboratory staff: Dr. Insub Shin, Mr. Daesik Kim, Mr. Sajjad Haider in the development of CAESAR II/EB is gratefully acknowledged.